July-November 2011 Highlights

NASA ENERGY AND WATER CYCLE STUDY

NEWS

NEWS Challenge:

Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

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Drought & Flood Extremes: X. Dong & Y. Deng
Evaporation & Latent Heating J. Famiglietti & C.A. Clayson
Energy & Water Cycle Climatology: M. Rodell & T. L'Ecuyer
Modeling & Water Cycle Prediction: M. Bosilovich & Y. Hu

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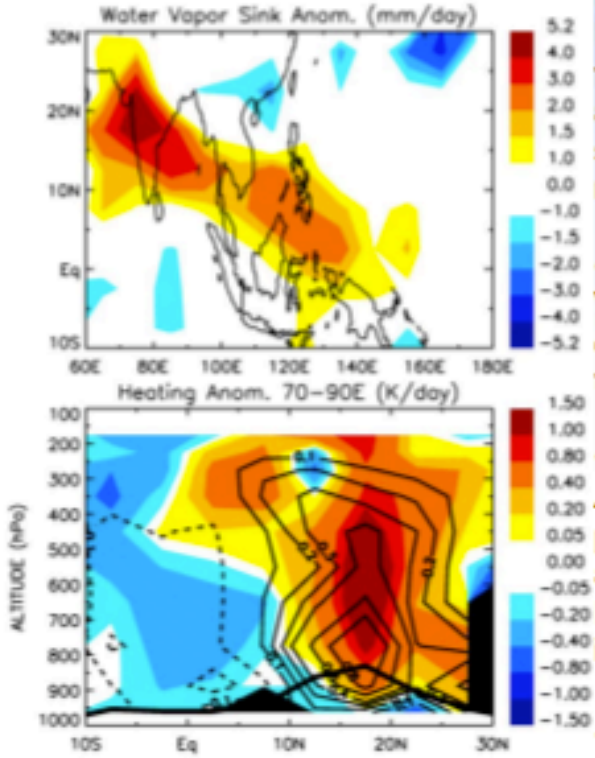
Indian Monsoon Water and Energy Budgets from AIRS and MERRA



Top: Column integrated water vapor loss anomalies at monsoon peaks.
Bottom: Heating anomalies at monsoon peaks (color); water vapor loss anomalies (contours);
and precipitation anomalies (the thick line at the bottom).

- **Why is this relevant?**

Precipitation of Indian Monsoon fluctuates at a time scale of 30-90 days. Maxima of rainfall is referred to as the monsoon peaks that may cause floods over India. Moreover, heat release in the process modifies the atmospheric circulation as a feedback mechanism. Many previous studies of such precipitation fluctuation mainly focused on using either model or reanalysis data.

- **What have we done?**

We use NASA AIRS water vapor soundings and MERRA winds to estimate 3-D water vapor fluxes and loss in the atmosphere. The AIRS temperature is used to estimate 3-D atmospheric heating rates.

- **Take-away messages:**

AIRS-based 3-D water vapor loss can reproduce features of monsoon precipitation fluctuation seen in TRMM. AIRS-based 3-D heating rates are also consistent with the heating rates estimated from TRMM. The 3-D datasets are used to investigate the feedback mechanism that involves latent heat release and convection during rainfall.

- **Implication**

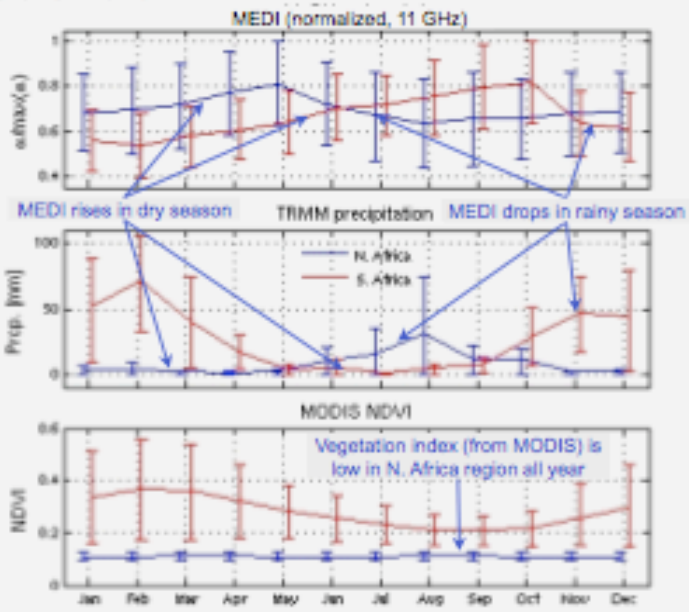
This work helps assess closure of atmospheric water and energy budgets by connecting NASA 3-D sounding data (e.g., AIRS) to 2-D data of precipitation/evaporation and radiative flux (e.g., NASA TRMM and NEWS).

Wong et al., *J. Climate*, 2011

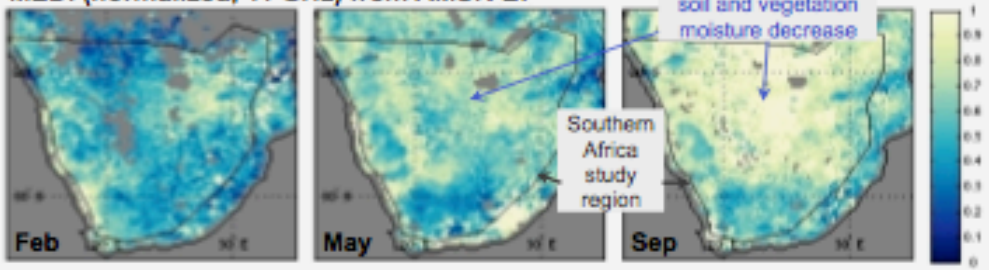
Publication Highlight:
Subsurface Emission Effects in AMSR-E Measurements: Implications for Land Surface Microwave Emissivity Retrieval

basis for use of microwave and infrared data for NEWS project "Toward Assimilation of Satellite Data in Modeling Water Vapor Fluxes over Land"

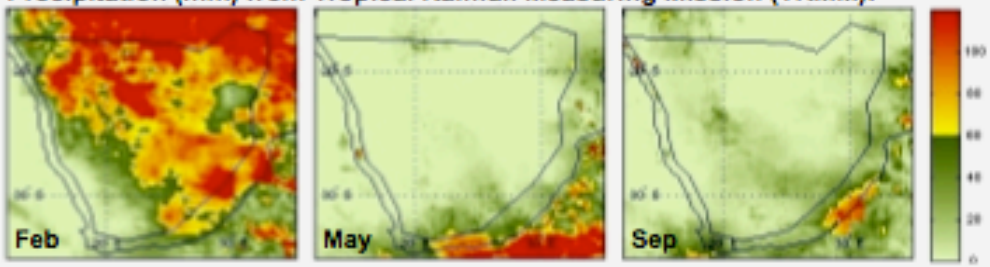
Analysis of microwave brightness temperatures show that variations in an index of microwave emission depth (MEDI) are measurable in areas worldwide. Where seasonal changes occur, examples show that they correspond to monthly changes in vegetation amount and surface wetness — factors that relate to surface evaporation and heat fluxes. A case study comparing seasonal change in northern and southern Africa provided evidence that 11-GHz MEDI may be sensitive to land surface moisture and vegetation changes during multi-month dry spells, whereas 11-GHz emissivities (used in conventional soil moisture retrievals) may be more sensitive to vegetation alone.



MEDI (normalized, 11 GHz) from AMSR-E:



Precipitation (mm) from Tropical Rainfall Measuring Mission (TRMM):



- It may be possible to improve land data assimilation algorithms for seasonally or continuously dry regions by exploiting these complimentary surface moisture and vegetation sensitivities.
- This NEWS project is analyzing MEDI along with other satellite data products in relation to land surface models and measurements from towers that measure evaporation, heat fluxes, and more.

*Journal of Geophysical Research, vol. 116, 2011, by J. F. Galantowicz, J.-L. Moncet, P. Liang, A. E. Lipton, G. Uymin, C. Prigent, and C. Grassotti.
Supported by NASA contract NNH04CC43C through the Science Mission Directorate (published 9/7/2011)

Diagnosing the Land-Atmosphere Coupling During Dry and Wet Extremes in the U. S. Southern Great Plains

Joseph A. Santanello, Jr. and Christa D. Peters-Lidard (PI), NASA-GSFC Code 614.3

NEWS and other community-based efforts (e.g. Landflux) have shown that current data and model products have significant uncertainty and spread in surface flux and other water and energy budget terms across global, continental, and regional scales.

In order for improvements to be made in the proper translation of **land surface states and anomalies** e.g. flood/drought) into **atmospheric quantities** (e.g. afternoon convection), a *stronger understanding and diagnosis of coupled model components and physics* must be acquired.

Hypothesis: Land-atmosphere interactions (L-A) play a critical role in supporting and modulating extreme dry and wet regimes, and must therefore be represented accurately in coupled models.

Methodology: Address deficiencies in models by developing diagnostics to quantify the strength and accuracy of the **Local L-A Coupling ('LoCo')** at the process-level. Using NASA's Land Information System coupled to the WRF regional model (**LIS-WRF**), diagnose the behavior and impact of land surface (LSM) and boundary layer (PBL) schemes during dry/wet extremes.

Contribution to NASA-NEWS: 1) Diagnostics of L-A that can be applied to any model, scale, or observation (in-situ or satellite). 2) Assessment of coupled model components and their integrated impacts through the L-A process chain. 3) Development of LIS-WRF as a testbed for GEWEX-directed intercomparison projects.

7-day Case Studies
-ARM-SGP domain
-14-20 June 2006
-14-20 July 2007

MERRA Monthly MDC
-'slv': T2m, Q2m
-'flx': PBLH, H, LE

Coupling Metrics
- Bowen ratios (β): H_{sfc}/LE_{sfc}, H_{ent}/LE_{ent}
- Entrainment ratios (A): H_{ent}/H_{sfc}, LE_{ent}/LE_{sfc}

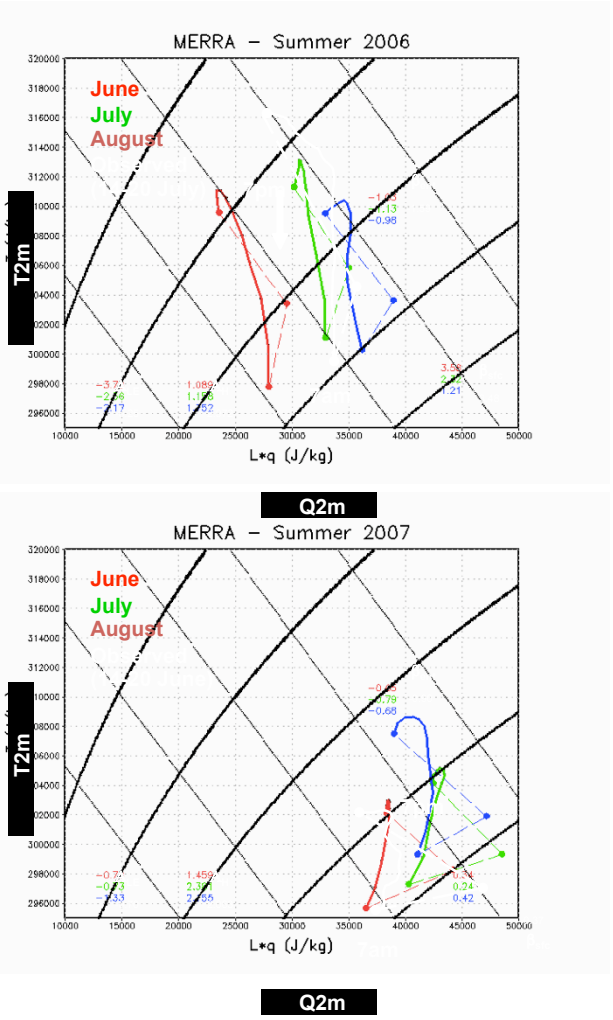


Figure 1. The diurnal evolution of T_{2m} and q_{2m} can be used to diagnose the land surface and PBL heat and moisture budgets (dashed), reflecting the balance reached in MERRA monthly mean diurnal cycles (colors) and 7-day composite observations at ARM-SGP CF.

Overall

- MERRA's MDCs perform well in terms of their land-PBL coupling relative to detailed in-situ obs

Extremes

- Even at monthly scales, extreme dry/wet regimes captured well by MERRA
- Obs show wider range due to localized extreme conditions, particularly PBLH and entrainment

Intercomparison

- MERRA's land-PBL coupling (LoCo) is comparable or better to high-resolution (1km) LIS-WRF simulations

Estimating Evapotranspiration using an Observation based Terrestrial Water Budget

Investigators: Matthew Rodell, Eric B. McWilliams, James S. Famiglietti, Hiroko K. Beaudoing, Joseph Nigro

Science issue: Evapotranspiration (ET) links the water and energy cycles, it is a process essential to the movement of water and energy around the Earth, and ***understanding and properly simulating ET is essential for weather forecasting and climate prediction.*** However, ET is difficult to measure, and different estimation techniques don't always produce the same results.

Approach: In this study we applied the terrestrial water budget equation over seven river basins around the world, with **observation based precipitation data, gauged runoff data, and terrestrial water storage changes from NASA's Gravity Recovery and Climate Experiment (GRACE) mission**, in order to estimate ET as a residual.

Models: Five land surface model simulations, two operational atmospheric analyses, and a recent global reanalysis product were evaluated over seven river basins based on our results.

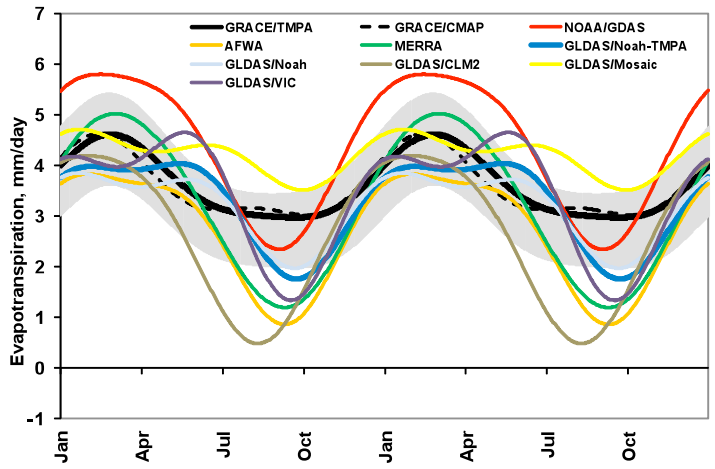


Figure 1. Mean annual cycle (plotted over two years) of ET from the terrestrial water budget approach (separately for two different precipitation data sources), two atmospheric analyses, a reanalysis, and five land surface model simulations, averaged over the Tocantins River basin in south-central Brazil. The gray area represents uncertainty in the GRACE/ TMPA water budget estimates.

Significance: We demonstrated for the first time that while uncertainty in the water budget based estimates of monthly ET are often too large for those estimates to be useful, the uncertainty in the mean annual cycle is small enough that it is practical to use it to evaluate other ET products. **An important outcome is that the water budget based ET time series in two tropical river basins, one in Brazil (Figure 1) and the other in central Africa, exhibit a weak annual cycle, which may help to resolve debate about the strength of the annual cycle of ET in such regions and how ET is constrained throughout the year. The methods described will be useful for water and energy budget studies, weather and climate model assessments, and satellite based evapotranspiration retrieval optimization.**

NEWS value added integration: The authors thank Sean Swenson and Felix Landerer for detailed discussion on GRACE errors. GRACE land data were processed by Sean Swenson, supported by the NASA MEASURES Program, and are available at http://grace.jpl.nasa.gov. The GRDC and U.S. Army Corps of Engineers are gratefully acknowledged for providing river gauge data used in this study.

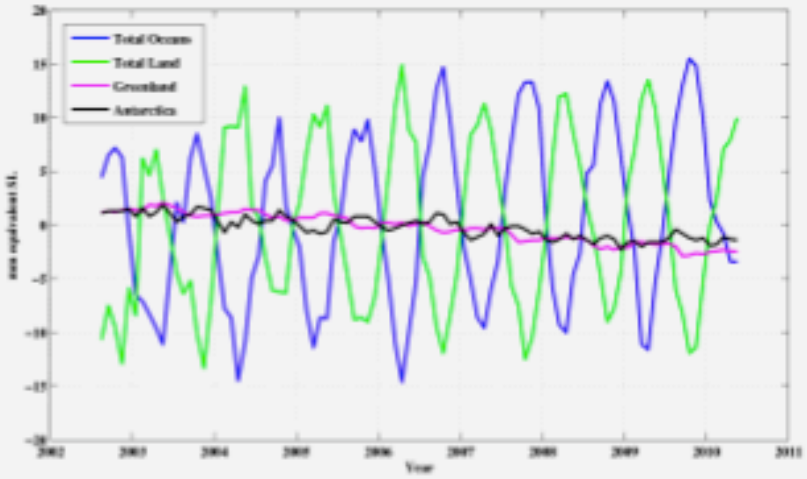
This work was funded by NASA's Energy and Water Cycle Study program and NASA Goddard Space Flight Center's Summer Institute in Earth Sciences program.

Publication:

Rodell, M., E. B. McWilliams, J. S. Famiglietti, H. K. Beaudoing,and J. Nigro , 2011: **Estimating evapotranspiration using an observation based terrestrial water budget, *Hydrological Processes,*** DOI: 10.1002/hyp.8369, Accepted.

11/2011

NEWS Team Quantifying Water Cycle Stregth and Acceleration



Water mass changes in global ocean, ice sheets and contients from GRACE, 2002-2010

Trends (mm/yr)
Ocean = 1.2± 0.3
Land = 0.3 ± 0.5
Greenland = -0.60 ± 0.1
Antarctica = -0.40 ± 0.2

Storage amplitude vs time, 2002-2010

- Metric of water cycle strength
- Change in amplitude (slope) is a metric of water cycle accereration
- Implies acceleration through 2006, slowdown through 2010
- Using NEWS datasets to attribute where changes are coming from and why

Famiglietti et al. 2011, in preparation

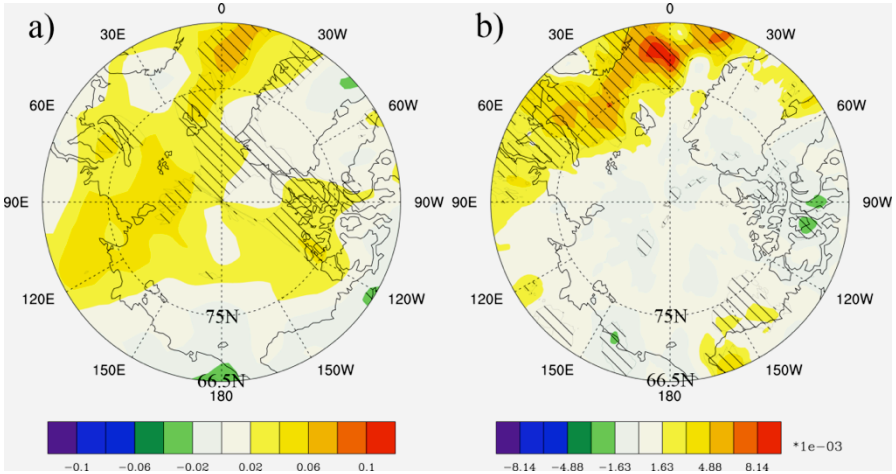
University of California Center for Hydrologic Modeling

A dynamical fingerprint of tropical Pacific sea surface temperatures on the decadal-scale variability of cool-season Arctic precipitation

Principal Investigator: Yi Deng

Science issue: The accumulation of snow and growth of ice cover in the Arctic during the Northern Hemisphere winter are important to the Earth's climate and depend significantly on the amount of precipitation that falls within the Arctic.

Findings: Analysis reveals a dynamical pathway that link central equatorial Pacific warming to strengthened stratospheric polar vortex, poleward shift of storm tracks, intensification of poleward moisture transport and thus above-normal snowfall in the Arctic in boreal winter.



Regression of the smoothed GPCP Arctic precipitation with the kinetic energy of 2-6 day eddies (i.e. synoptic-scale eddies or midlatitude cyclones) at 850 mb. Shading: 90% significance

-Important feature: Positive regression values between 30W and 30E, signifying Arctic precipitation is high when there is an increase in midlatiude cyclone activity in this region.

b) Regression of the smoothed GPCP Arctic precipitation with the synoptic eddy meridional moisture transport (v'q', v=meridional wind, q=specific humidity).

-Important feature: Positive regression values between 30W and 30E indicates strengthened meridional moisture transport in this region leads to above-normal Arctic precipitation.

Significance: Noteworthy correlations found between the tropical Pacific sea surface temperature (SST) variability and the Arctic precipitation across decadal timescales. The occurrence of central equatorial Pacific warming leads to a stronger stratospheric polar vortex, i.e., a positive phase of Arctic Oscillation (AO). A positive AO is in turn coupled to a poleward shift of the Pacific and Atlantic storm tracks that ultimate enhances poleward transport of moisture through synoptic-scale eddies (i.e., midlatitude winter cyclones). The impact of SST on the strength of polar vortex is established through the amplitude change of the midlatitude planetary waves.

Take away message: Understanding the tropical air-sea coupled system helps understand and predict the future of Arctic environment.

NEWS value added integration:. The CMAP, GPCP precipitation data and the NOAA Interpolated Outward Longwave Radiation (OLR) data used in this study were provided through NOAA/ OAR/ ESRL (http://www.esrl.noaa.gov/psd/). The HadISST data set was provided by the UK Met Office www.metoffice.gov.uk/hadobs). MERRA reanalysis data were acquired from the NASA Global Modeling and Assimilation Office (GMAO) and the GES DISC. Bradley M. Hegyi was suported by the NASA Earth and Space Science Fellowship grant , and Yi Deng was supported by NASA Energy and Water Cycle Study (NEWS).

Hegyi, B. M., and Y. Deng (2011), A dynamical fingerprint of tropical Pacific sea surface temperatures on the decadal-scale variability of cool-season Arctic precipitation, *J. Geophys. Res.*, 116, D20121, doi: 10.1029/2011JD016001 (29 October, 2011)

Downstream modulation of North Pacific atmospheric river activity by East Asian cold surges

Principal Investigator: Yi Deng

Science issue: ***this study investigates for the first time*** the impact of the East Asian cold surge (EACS)-excited disturbances on the activity of atmospheric rivers (ARs) over the North Pacific.

Data and Methods: primary fields analyzed in this study include: surface air temperature, precipitation rate, column integrated water vapor, isobaric-surface winds, and geo-potential height and specific humidity

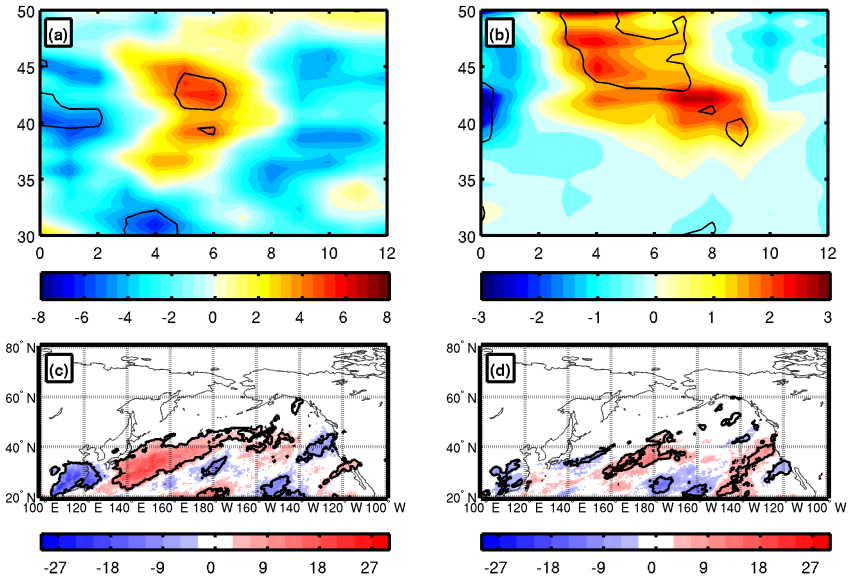
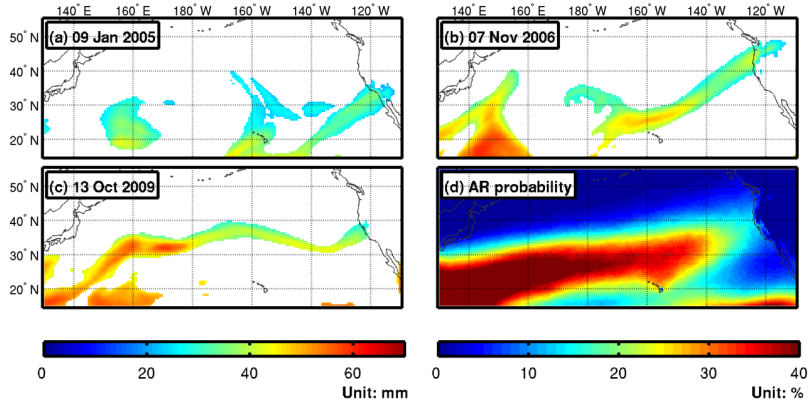


Figure: (a) Composite anomalies of the daily occurrence probability of ARs along 124°W (in percentage); (b) composite anomalies of the precipitation rate along 124°W (unit:mm/day); c) composite anomalies of the daily occurrence probability of ARs averaged over Day 0 to Day 2 (in percentage); d) same as Figure 3c, but for average over Day 4 to Day 6. Areas enclosed by solid contours are significant at the 90°0 level. Day 0 is defined as the time when an East Asian cold surge reaches its peak intensity.

Findings: analysis of NASA MERRA data shows that the East Asian cold surge (EACS) significantly increases the probability of atmospheric river formation near the west coast of U.S. five days after the surge and this enhancement of probability is achieved through the low-frequency waves excited by the EACS.

Significance: This work is important because it found that the East Asian cold surge in winter acts as a critical remote forcing for the occurrence of extreme moisture transport and and rainfall (flooding) along the west coast of the U.S.

Take away message: Extended predictability of extreme rainfall and flooding in the western U.S. can be obtained by improving the model representation of the characteristics of East Asian cold surge and the associated modes of low-frequency variability over the North Pacific.



NEWS value added integration:

The MERRA data used in this study were provided by NASA/GSFC.

Jiang, T. and Y. Deng (2011), Downstream modulation of North Pacific atmospheric river activity by East Asian cold surges, *Geophys. Res. Lett.*, 38, L20807, doi:10.1029/2011GL049462.(10/29/11)